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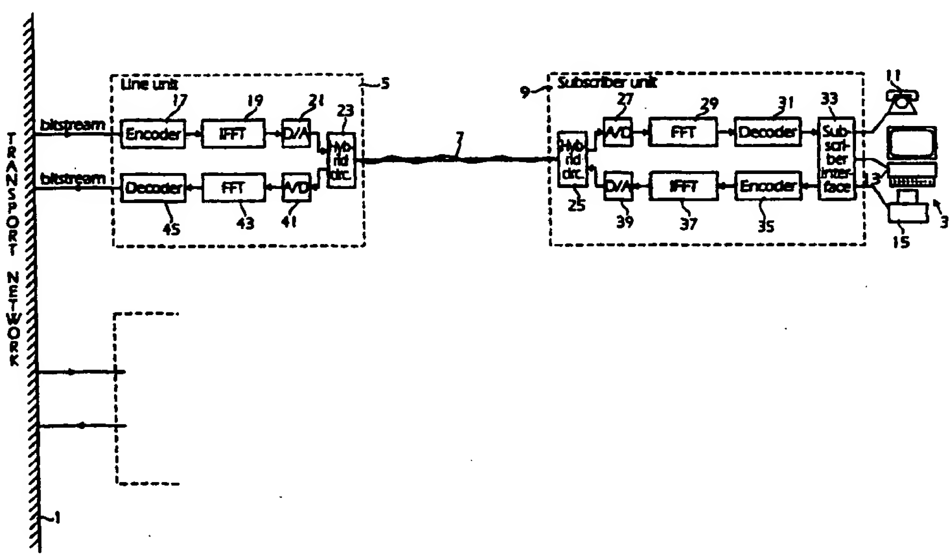
(54) Title: A DIGITAL SYSTEM FOR SUBSCRIBER LINES ALLOWING HIGH BIT RATES

(57) Abstract



A subscriber line connection for very high bit rates in a telecommunication network comprises a line unit (5) connected to a transport network (1) and through a twisted two–wire cable (7) to a subscriber unit (9). Information is communicated bidirectionally on the cable using frequency multiplexing on orthogonal carriers. The line and subscriber units each comprise modulating units (19, 37) determining an inverse discrete fourier transform on incoming symbols and demodulating units (29, 43) for making a direct discrete fourier transform on a sampled stream of the signal forwarded on the cable (7). The transforming units (19, 29) used for transmission in one direction use carriers which are different from those used by the transforming units (37, 43) in the opposite direction. The carriers are selected so that in at least one of the directions special properties of the transforms are used for reducing the number of calculations which are required. In the direction from the subscriber (3) only carriers having even indices can be used in the transforming unit (37) and then the output signal sent on the cable (7) will consist of a repeated sequence having half the length of that obtained when all carriers are used, so that only a sequence having half the length has to be calculated and repeated. In the transforming unit (43) receiving such a twice repeated signal, the received symbols can be subdivided into two equal segments which are added to each other and then a reduced transforming operation is executed. In the opposite direction the transforming operation using all carriers can always be calculated. Then also, the lowest frequencies can be always assigned to this direction towards the subscriber, since the transmission in the opposite direction may be especially sensitive to noise or interference at low frequencies which thus should not be used.

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A DIGITAL SYSTEM FOR SUBSCRIBER LINES ALLOWING HIGH BIT RATES

TECHNICAL FIELD

The present invention relates to digital systems for subscriber lines allowing communication at high bit rates and in particular at very high bit rates.

BACKGROUND

In telecommunication networks there presently exits a need for extending communications at high bit rates up to the user end of the lines and even the need to provide high speed digital communication into apartments, private homes and estates etc. The cost for a cabling system up to the corresponding geographical locations should thus not be too high and efforts of using ordinary twisted wire pairs for such communication have been made.

A proposed way of accomplishing such high speed communication is disclosed in the published International patent application WO 97/06619 for Telia AB and Mikael Isaksson. This method is also briefly described in the document Mikael Isaksson et al. of Telia Research AB, "Zipper - a Duplex Scheme Proposal for VDSL Based on DMT", ANSI T1E1.4/97 - 137, T1E1.4 Technical subcommittee working group. In this prior system adapted for VDSL (Very High Bit Rate Digital Subscriber Line) duplex or bi-directional communication, where thus signals are sent in two directions on the same two wires, is performed using DMT (Discrete Multi Tone modulation). In this method, in each direction the information is modulated on a plurality of carriers having distinct frequencies, the modulation and carriers being selected generally according to the method called OFDM (Orthogonal Frequency Division Multiplexing) utilizing orthogonal carriers. In the communication the carrier frequencies are divided in such a way that some of them are used in the downstream direction, i.e. towards the subscriber, and other frequencies in the upstream direction, i.e. from the subscriber towards the switch. Then a true duplex communication is obtained, in which information is transmitted all the time in both directions. This method may be called OFDD (Orthogonal Frequency Division Duplexing). In a preferred embodiment every second carrier frequency is used in one direction and the remaining ones, thus also every second frequency, is used for signals propagating in the opposite direction. Thus even carriers can be used in the downstream direction and odd carriers in the upstream direction.

A disadvantage of the this proposed method is that at each end of a communication channel both FFT (Fast Fourier Transform) and IFFT (Inverse Fast Fourier Transform) have to be calculated at the same time what for instance is avoided in the competing method TDD (Time Division Duplexing). This may require processors working at very high clock frequencies at both ends of the communication channel.

The use of orthogonal carriers and the associated transforming methods in the area of digital television broadcasting are described in William Y. Zou et al., "COFDM: An overview", IEEE Transactions on Broadcasting, Vol. 41, No. 1, March 1995, pp. 1 - 6.

The basic theory is also discussed in Leonard J. Cimini, Jr., "Analysis and simulation of a digital mobile channel using orthogonal frequency division multiplexing", IEEE Transactions on Communications, Vol. 33, No. 7, July 1985, pp. 665 - 675 and the published European patent application EP-A1 0 616 445.

A system using orthogonal frequency division multiplexing is disclosed in the published European patent application 0 668 678 in which a double number of channels can be transmitted and received without a considerable increase of the processing complexity. This system and the corresponding method are thus not concerned with simplifying the calculations which have to be made but instead using the available processor for transmitting more information. This system does not use the "zipper" assignment of carrier frequencies proposed in the cited International patent application WO 97/06619 and the document by Mikael Isaksson et al.

SUMMARY

It is an object of the invention to provide a method of transmitting information on a single line or a communication channel bidirectionally, e.g. on a true duplex line, allowing that a minimum of calculations have to be made at both ends of the line or communication channel.

It is another object of the invention to select carrier frequencies when transmitting information on a line or a communication channel so that OFDD can be effectively implemented.

It is another object of the invention to select the carriers in transmitting information on a line so that a reduction of noise or interference is obtained when using OFDD.

Thus, if selecting the carriers in a suitable way in the up- and downstream directions some properties of the DFT (Discrete Fourier Transform) and IDFT (Inverse Discrete Fourier Transform) can be utilized for reducing the number of calculations which are required. Thus it can be demonstrated that if a DMT transmitter only uses carriers having even indices the output signal in the time domain will consist of a repeated sequence having half the length of the original one. It can be utilized in such a way that a sequence having half the length is calculated and then is repeated. In the similar way, if the DMT transmitter only uses carriers having indices that are multiples of four a sequence will be repeated four times, the DFT or IDFT will have a quarter of the length of the original one and the resulting sequence will then have to be repeated four times, etc.

Thus, a telecommunication network is designed in the general way proposed in the cited International patent application WO 97/06619 and the document by Mikael Isaksson et al. of Telia Research AB. The network generally comprises at least two nodes, which communicate information bidirectionally with each other. Each of the nodes comprises first transforming means which are arranged to transform digital information to be transmitted to the other node from a frequency domain to a time domain and in this

transformation the first transforming means uses orthogonal carriers in the time domain, the transformation then producing transformed information. Each node further comprises forwarding means connected to the first transforming means, the forwarding means forwarding the transformed information to the other nodes. Further, there is in each node receiving means for receiving information from the other node and each node further comprises second transforming means connected to the receiving means. The second transforming means is arranged to transform information received from the receiving means from a time domain to a frequency domain. The first transforming means and the second transforming means are arranged to transform information according to a discrete fourier transform or an inverse discrete fourier transform. The first transforming means in one node uses frequencies of the carriers different from those used by the other node and the first transforming means further determines the discrete fourier transform or the inverse discrete fourier transform for only a fraction of the carriers and then it essentially repeats the transformed values obtained when making the transforming a required or an appropriate number of times. Alternatively or in addition thereto the carriers used for communication in one of the directions can include all frequencies within a low frequency band.

A second transforming means in the other node may determine the inverse discrete fourier transform or the discrete fourier transform respectively by dividing the received information in segments, then essentially adding at least two consecutive segments to each other and finally calculating transformed values from the result of the addition.

Advantageously, the first transforming means in one node and the second transforming means in the other node use only carriers which have even indices.

The first transforming means in a node can comprise encoder means arranged to encode information to be transformed to symbols which have been adapted to be transformed according to a discrete fourier transform or an inverse discrete fourier transform using the fraction of the carriers. The carriers included in the fraction have preferably indices, which are multiples of powers of 2, i.e. of 2, 4 or 8, etc.

Additional objects and advantages of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and obtained by means of the methods, processes, instrumentalities and combinations particularly pointed out in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

While the novel features of the invention are set forth with particularly in the appended claims, a complete understanding of the invention, both as to organization and content, and of the above and other features thereof may be gained from and the invention will be better appreciated from a consideration of the following detailed description of non-limiting embodiments presented hereinbelow with reference to the

accompanying drawings, in which:

Fig. 1 is a block diagram of a portion of a network for communicating with a subscriber,

Fig. 2 is a block diagram illustrating the operation of an efficient transforming unit used for modulating information to be transmitted,

Figs. 3a and 3b are schematic pictures illustrating an adding operation for recovering a transmitted short sequence,

Fig. 4 is a diagram illustrating the operation of an efficient transforming unit used for demodulating received information, and

Fig. 5a and 5b are diagrams illustrating the assignment of carrier frequencies for asymmetric communication.

DETAILED DESCRIPTION

The system depicted as a block diagram in Fig. 1 is a portion of a telecommunication network illustrating the connections from a transport network 1 to subscribers 3 using DMT (Discrete Multi Tone) modulation of the transmitted information. Bit streams arrive to and come from a line unit 5 from and to the transport network 1 respectively. From the line unit 5 a twisted copper wire-pair 7 extends up to a subscriber unit 9, which can be attached to a telephone set 11, a computer 13, a telefacsimile device 15 and other electronic input and output devices used by the subscriber 3. The bit stream arriving to the line unit 5 from the transport network 1 is encoded in an encoder 17 in which appropriate symbols are formed which are input to an IFFT unit 19 connected to the output terminal of the encoder 17. The output terminal of the IFFT unit 19 is connected to a digital-to-analog converter 21, the output of which is connected through a hybrid circuit 23 to the wire 7. In the subscriber unit 9 the twisted wire 7 is in a similar way connected to a hybrid circuit 25. The signals from the hybrid circuit 25 are fed to an analog-to-digital converter 27, the output of which is connected to an FFT unit 29 performing calculations, the result of which are input to a decoder 31 connected to the output of the FFT unit 29. The output of the decoder 31 is connected to a subscriber interface 33 in which the received and decoded bits are processed according to the unit intended to receive the bitstream, i.e. according to whether it is a e.g. a voice message or a data signal. The subscriber interface 33 thus has terminals to which the various subscriber devices 11, 13, 15, etc. are connected.

In a similar way a signal fed to the subscriber unit 9 from one of the subscriber devices 11, 13, 15, etc. are processed by the subscriber interface 33 and the resulting bit stream is encoded in an encoder 35. The encoded symbols are then processed in an IFFT unit 37 and the transformed data are converted to analog shape in a digital-to-analog converter 39. The signal output from the digital-to-analog converter 39 is fed to the hybrid circuit 25 from which the analog signal is transmitted on the twisted wire pair 7. The transmitted signal is received by the corresponding hybrid circuit 23 in the line unit

5 and is converted to digital shape by an analog-to-digital converter 41. The digital signal is processed by an FFT unit 43 and the resulting symbols are decoded in a decoder 45, which produces a bit stream on a line to the transport network. The encoders, decoders, digital-to-analog and analog-to-digital converters and hybrid circuits are elements well known in the art of transmitting signals in communication systems using orthogonal carriers and in a two wire subscriber connection respectively. A hybrid circuit 23, 25 thus receives signals from a line or subscriber unit and transmits them on the twisted wire 7, producing a smallest possible deflected signal which in a non-desired way is simultaneously or automatically fed to the output terminal of the hybrid circuit which is connected to the inner portion of the respective line and subscriber units, i.e. to the analog-to-digital converters provided therein.

The DMT (Discrete Multi Tone) modulation and demodulation used in the subscriber connection illustrated in Fig. 1 generally comprises that first the input symbols arriving serially are converted to a suitable parallel shape by the encoders 17, 35 and that then a plurality of carriers are modulated by the transforming or IFFT units 19, 37. The modulated carriers are added to each other in a final step in the IFFT units and the result is fed to the digital-to-analog converters 21, 23. A corresponding process is performed when demodulating the sampled received signal.

The modulating and demodulating processes are very efficiently implemented by generally using the inverse discrete fourier transform (IDFT) for modulation and the direct discrete fourier transform (DFT) for demodulation. The calculation schemes of the IDFT and DFT can be refined to various forms of the inverse fast fourier transform IFFT for modulating and the direct fast fourier transform FFT for demodulating, as illustrated in the figure by the IFFT units 19, 37 and FFT units 29, 43.

Communication in one direction will now be discussed. For a symbol vector $\{X_0, X_1, \ldots X_{2N-1}\}$ obtained by coding (in 17 or 35) an incoming bitstream, the time domain sequence $\{x_0, x_1, \ldots x_{2N-1}\}$ computed by means of the inverse discrete fourier transform (in 19 or 37) is given by

$$x_n = \frac{1}{2N}\sum_{m=0}^{2N-1} X_m \cdot W_{2N}^{-mn} \qquad (1)$$

for $n = 0, 1, \ldots, 2N-1$, where

$$W_N = e^{-j\frac{2\pi}{N}} \qquad (2)$$

If we assume that only even components in the original symbol are present, i.e. $X_{2k+1} = 0$, $k = 0, 1, \ldots, N-1$, which means that the preceding coding process in the encoder 17, 35 must be adjusted thereto, the following equation is obtained

$$x_n = \frac{1}{2N}\sum_{k=0}^{N-1} X_{2k}\cdot W_N^{-kn} \qquad (3)$$

However, W_n is periodic with a period N and thus x_n is periodic with the same period, i.e.

$$x_n = x_{n+N} \qquad (4)$$

Thus, the time domain sequence $\{x_0, x_1, \ldots x_{2N-1}\}$ may be obtained by repeating the sequence $\{x_0, x_1, \ldots x_{N-1}\}$ being the inverse discrete fourier transform of the symbol vector with the zeroes removed, i.e. the time domain sequence is actually $\{x_0, x_1, \ldots x_{N-1}, x_0, x_1, \ldots x_{N-1}\}$.

In the case where only carriers, which have indices which are multiples of four, exist in the original symbol vector, there is a corresponding 4-fold repetition in the time sequence in which the first components are repeated four times in the time domain sequence. The corresponding condition is true for components the indices of which are multiples of eight, sixteen, etc., the transformation then resulting in a 8-fold, 16-fold, ... respectively repetition of the first transformed values. This is illustrated in Fig. 2, in which in a block 201 an IFFT is made having a length reduced by the factor R producing a sequence of values which are repeated R times in the repetition block 203 producing the values to be transferred to a digital-to-analog converter.

In the case where only odd-numbered carriers are used for transmission in one direction, i.e. when $X_{2k} = 0$, $k = 0, 1, \ldots, N-1$, the calculation corresponding to that outlined above will be more complicated. Then instead the signal must be repeated but with an inverted sign. In that case also an extra complex multiplication per sample must be made on the time domain side.

Methods exist for calculating an FFT of 2N points for a real input signal by means of an FFT having only N points, see J.G. Proakis and D.G. Manolakis, "Digital Signal Processing", MacMillan Publishing Company, 1992, pp. 708 - 714. Similar methods may be derived for an IFFT of 2N points for a real output signal. For the case of only odd-numbered carriers these methods which are adapted for a real input or output signal respectively cannot be directly applied due to the more complicated repetition procedure. Thus, in the simplest practical case the carrier indices should preferably be multiples of 2, 4, 8, etc. for transmission in one direction. For the remaining frequencies which are used in the opposite transmission direction a discrete fourier transform using all carriers can be computed.

In the receiver it is also possible to reduce the number of calculations for the demodulation, since the discrete fourier transform has a periodicity corresponding to that described above for the inverse fourier transform. Then, as illustrated in Figs. 3a and 3b a received symbol is divided into the relevant number of smaller portions having all the

same length, and these portions are added. A reduced FFT for a smaller number of indices is then calculated. For instance, for carriers having even indices each received symbol is divided into two equally long parts which are added to each other. Further, the adding operation results in that all non-desired carriers are cancelled and that in the receiver noise and interference is reduced and further, for example in the case of only even indices being used, that an FFT for only half the number of indices has to be calculated in the receiver.

A simple circuit for making the addition is illustrated in Fig. 4. The incoming sample stream passes through a summation node 401, from one input thereof to the output, to a memory 403 having such a length that it can only accommodate the appropriate divided, shorter length. The first part of the incoming block of time domain samples passes through the memory 403 and is guided by a switch 405 back to the summation node 401, to a second input thereof, and is there summed to the next part of the incoming stream. This is repeated the required number of times and then the switch 405 is brought to another position to feed the added, smoothed stream to an FFT unit 407 calculating the frequency domain values for a reduced number of input values.

In symmetric full duplex communication on the communication channel, in particular on the twisted wire-pair 7, information can be transmitted with equal rates in the two opposite directions. Then, as been suggested in the prior art, carriers having even indices can be used in one direction and carriers having odd indices can be used in the opposite direction. For the direction using even numbered carriers the amount of calculations for modulating and demodulating can be reduced to one half of the amount of calculations required for general case when the discrete fourier transform for all carriers is calculated. For the direction using odd numbered carriers it may be preferred to use the transform as calculated for all carriers and, thus totally, the amount of calculations saved compared to the case where the transform using all carriers has to be calculated in both directions will be (1 - (1 + 1/2)/2 =) 1/4. In some cases symmetric communication is not required, e.g. for sending video data such as movies to a home, and then the available carrier frequencies can be assigned in an asymmetric way, e.g. so that every fourth or every eighth frequency of the total number of frequencies are used for sending information from the subscriber end. Then the amount of calculations needed in the direction from the subscriber, in the transform units 37 and 43, will be 1/4 and 1/8 respectively of the amount of calculations required in the transform using all carriers what will giving savings of calculations amounting to 3/8 and 7/16 respectively.

In the preferred, non-limiting embodiment thus the transform using all carriers may always be calculated in the downstream direction, towards the subscriber. This further results in that some of the carriers used in the upstream direction, from the subscriber, do not have be used for transmitting information in that direction but can instead be used for transmitting in the opposite direction. This can be utilized for planning the selection

of frequencies used. For example, if for interference reasons low carrier frequencies should be avoided in the upstream direction, these frequencies can be used for downstream transmission, by modifying the encoding processes correspondingly which are executed by the encoders 17, 35.

In Fig. 5a the available frequencies are illustrated by juxtaposed rectangles arranged in a row, the position of a rectangle in the row indicating the index or number of the represented frequency. For the case of upstream communication using carriers having indices which are multiples of four, every fourth frequency can be used for upstream signalling, as is indicated by the rectangles filled with a cross-hatching including thick lines. As is illustrated in Fig. 5b, the lower frequencies thereof can be transferred to transmission in the downstream direction as indicated by the rectangles filled with a cross-hatching having thin lines.

Thus, a telecommunication network has been described having simplified calculation requirements allowing the use of e.g. less powerful processors. This is achieved by using some symmetric or possibly antisymmetric properties of the mathematical transforms used.

While specific embodiments of the invention have been illustrated and described herein, it is realized that numerous additional advantages, modifications and changes will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details, representative devices and illustrated examples shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents. It is therefore to be understood that the appended claims are intended to cover all such modifications and changes as fall within a true spirit and scope of the invention.

CLAIMS

1. A telecommunication network comprising at least two nodes, which communicate information bidirectionally with each other, each of the nodes comprising

first transforming means for transforming digital information to be transmitted to another one of the nodes, the first transforming means being arranged to transform the digital information from a frequency domain to a time domain using orthogonal carriers in the time domain in the transforming in order to produce transformed information,

forwarding means connected to the first transforming means, the forwarding means being arranged to forward the transformed information to the another one of the nodes, and

receiving means for receiving information from the another one of the nodes,

second transforming means connected to the receiving means for transforming information received from the receiving means from a time domain to a frequency domain,

the telecommunication network being **characterized in**

that the first transforming means and the second transforming means are arranged to transform information according to a discrete fourier transform or an inverse discrete fourier transform,

that the first transforming means in one of the nodes is arranged to use frequencies of the orthogonal carriers which are different from frequencies of the orthogonal carried used by another one of the nodes,

that the first transforming means in a first one of the nodes is arranged to determine the discrete fourier transform or the inverse discrete fourier transform for a fraction of the orthogonal carriers in order to produce transformed values and then essentially repeating the transformed values a required number of times.

2. A network according to claim 1, **characterized in** that a second transforming means in a second one of the nodes, which is different from the first one of the nodes, is arranged to determine the inverse discrete fourier transform or the discrete fourier transform respectively by dividing the received information in segments, essentially adding at least two consecutive segments to each other and calculating transformed values from the result of the addition.

3. A network according to any of claims 1 - 2, **characterized in** that the first transforming means in one of the nodes and the second transforming means in another one of the nodes are arranged to use only orthogonal carriers which have even indices.

4. A network according to any of claims 1 - 3, **characterized in** that the first transforming means in a first one of the nodes comprises encoder means, the encoder means being arranged to encode information to be transformed to symbols adapted to be transformed according to a discrete fourier transform or an inverse discrete fourier transform using the fraction of the orthogonal carriers.

5. A network according to any of claims 1 - 4, **characterized in** that the orthogonal carriers included in the fraction have indices, which are multiples of powers of 2, i.e. of 2, 4 or 8, etc.

6. A network according to any of claims 1 - 5, **characterized in** that the orthogonal carriers used for communication in one of the directions include all frequencies within a low frequency band.

7. A telecommunication network comprising at least two nodes, which communicate information bidirectionally with each other, each of the nodes comprising

first transforming means for transforming digital information to be transmitted to another one of the nodes, the first transforming means being arranged to transform the digital information from a frequency domain to a time domain using orthogonal carriers in the time domain in the transforming in order to produce transformed information,

forwarding means connected to the first transforming means, the forwarding means being arranged to forward the transformed information to the another one of the nodes, and

receiving means for receiving information from the another one of the nodes,

second transforming means connected to the receiving means for transforming information received from the receiving means from a time domain to a frequency domain,

the telecommunication network being **characterized in**

that the first transforming means and the second transforming means are arranged to transform information according to a discrete fourier transform or an inverse discrete fourier transform,

that the first transforming means in one of the nodes is arranged to use frequencies of the orthogonal carriers which are different from frequencies of the orthogonal carried used by another one of the nodes, and

that the orthogonal carriers used for communication in one of the directions include all frequencies within a low frequency band.

Fig. 1

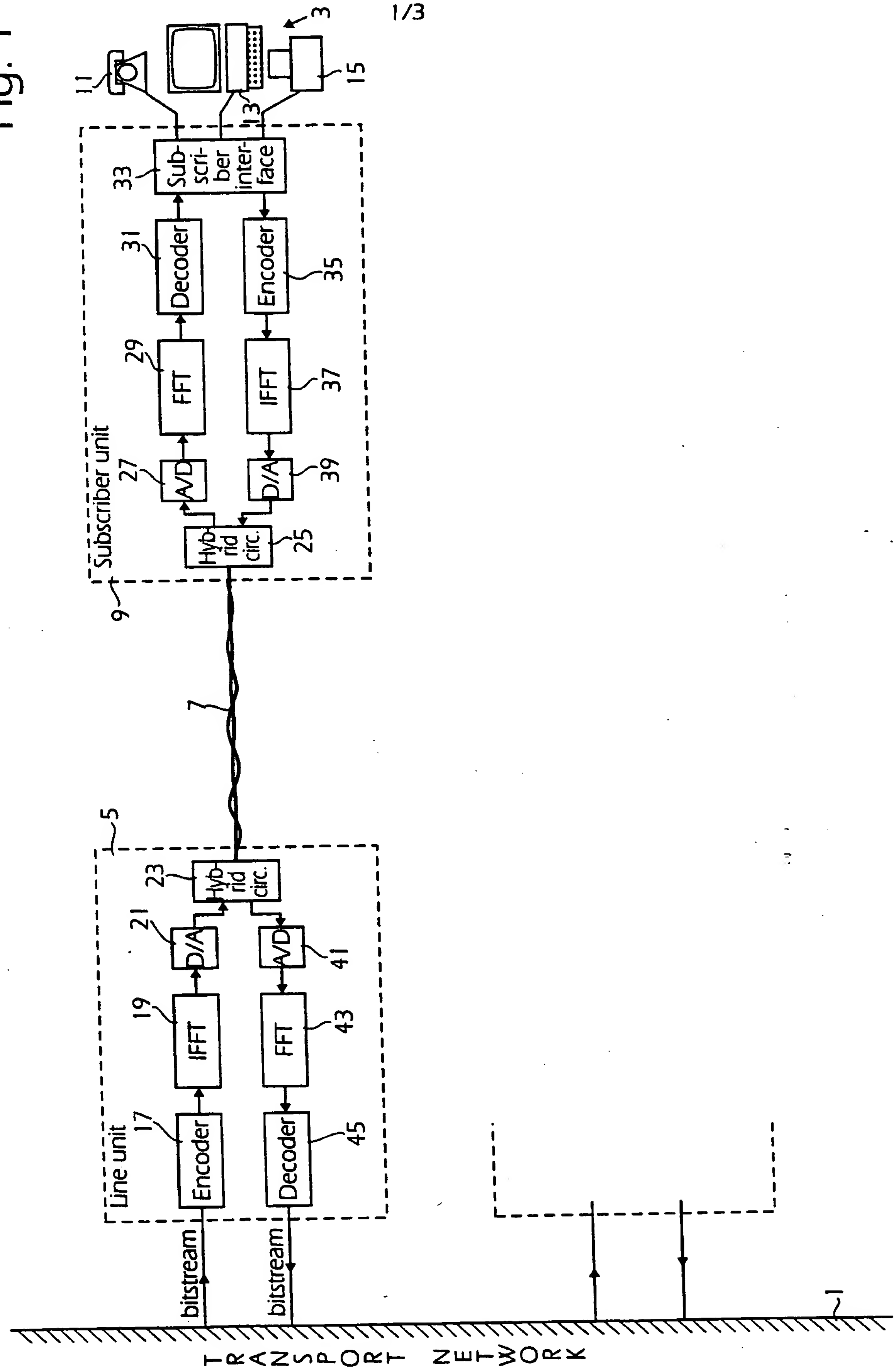

3
11
13
15
33
Sub-scri-ber inter-face
31
Decoder
35
Encoder
29
FFT
37
IFFT
Subscriber unit
27
A/D
39
D/A
Hyb-rid circ.
25
9
7
5
23
Hyb-rid circ.
21
D/A
41
A/D
19
IFFT
43
FFT
17
Line unit
Encoder
45
Decoder
bitstream
bitstream
1
TRANSPORT NETWORK

Fig. 2

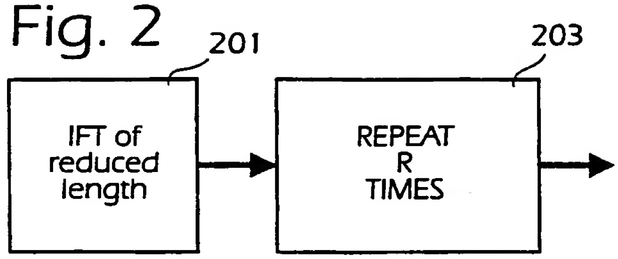
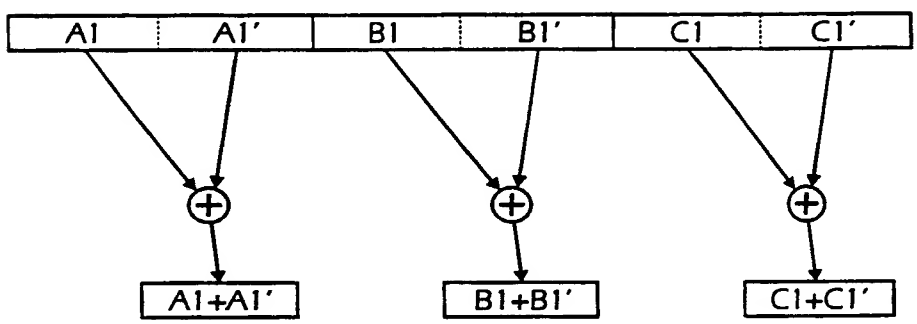
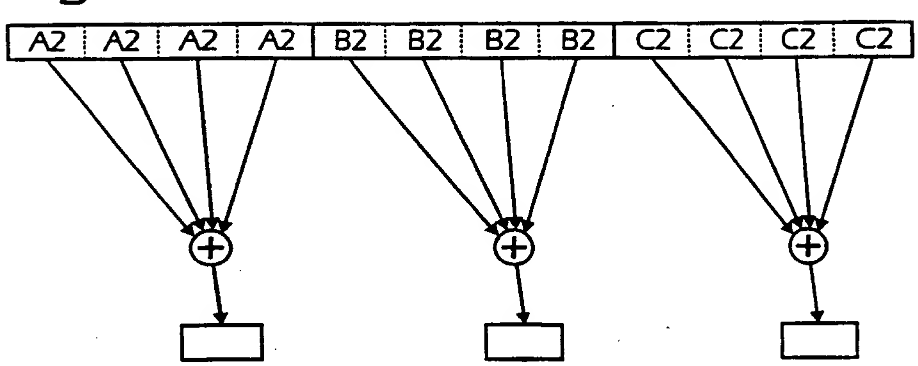


Fig. 3a



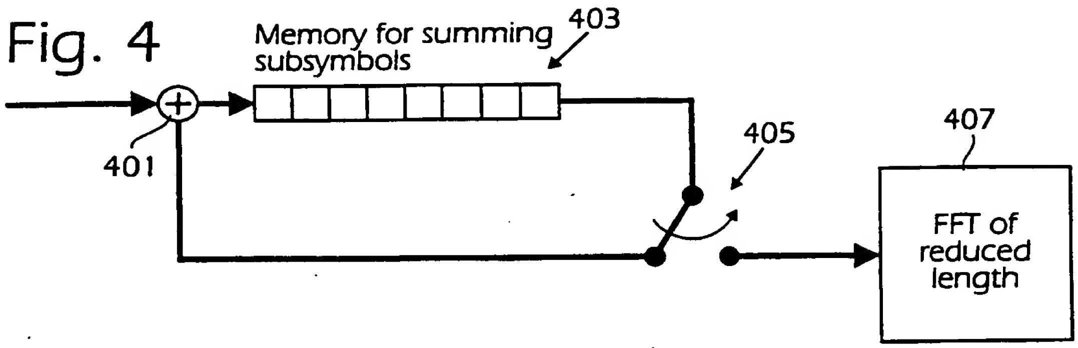
Two subsymbols are added (symmetric case)

Fig. 3b



Four subsymbols are added (symmetry 1:4)

Fig. 4



(SYMMETRY FACTOR R = 4)

Fig.5a

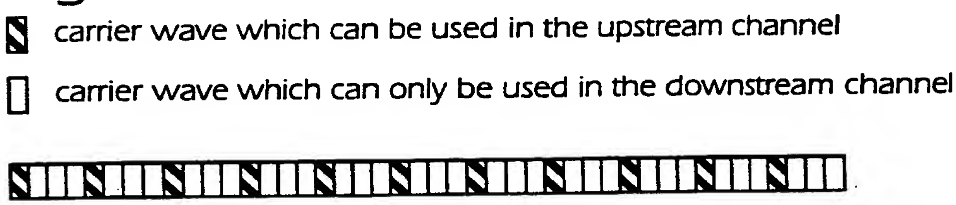


Fig.5b

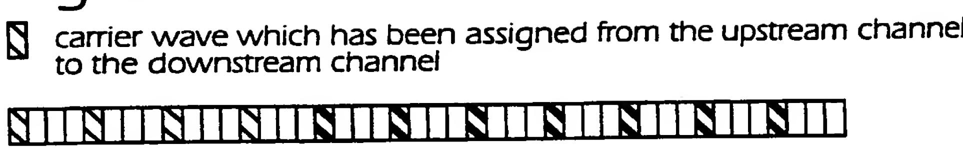
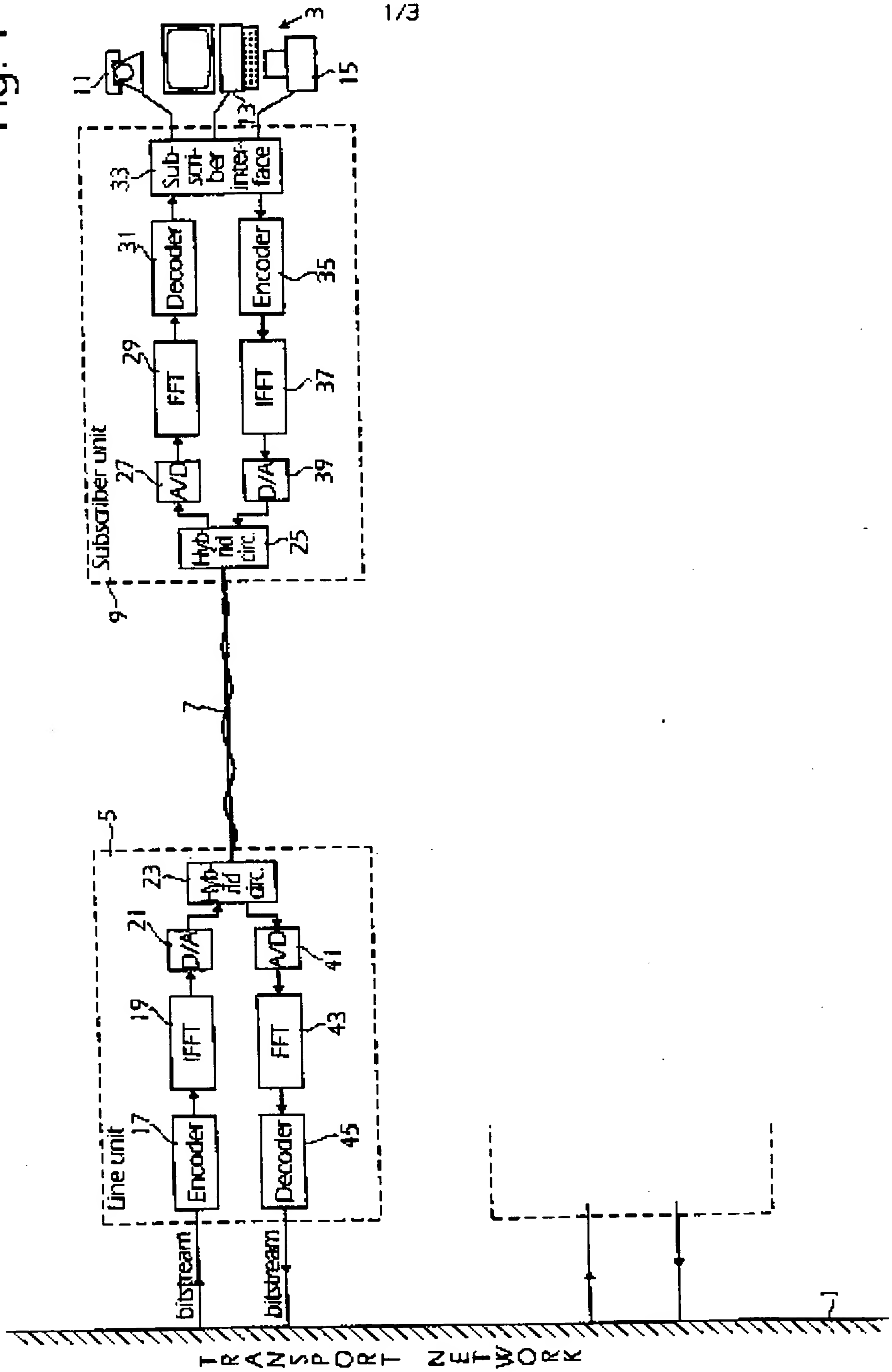


Fig. 1



3
11
13
15
33
Sub-
scri-
ber
inter-
face
31
Decoder
35
Encoder
29
FFT
37
IFFT
27
A/D
39
D/A
25
Hyb-
rid
circ.
Subscriber unit
9
7
5
23
Hyb-
rid
circ.
21
D/A
41
A/D
19
IFFT
43
FFT
17
Encoder
45
Decoder
Line unit
bitstream
bitstream
TRANSPORT NETWORK

Fig. 2

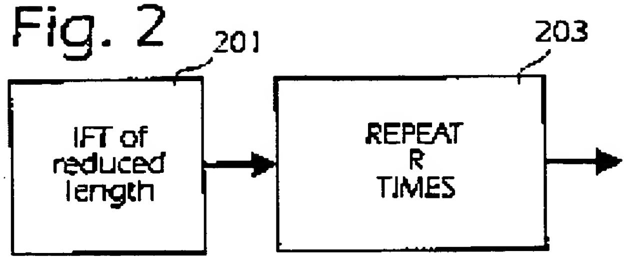
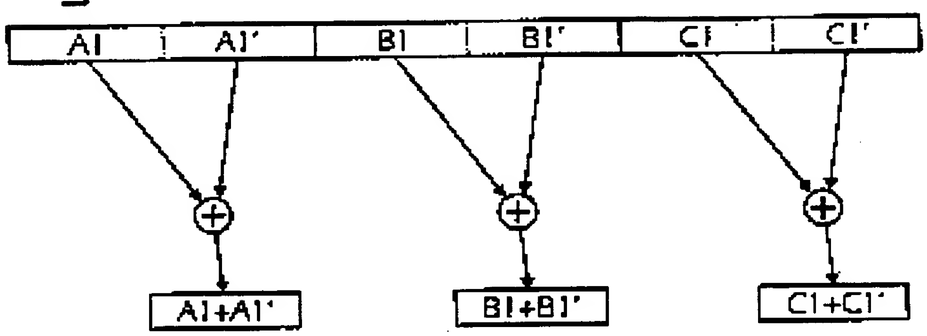
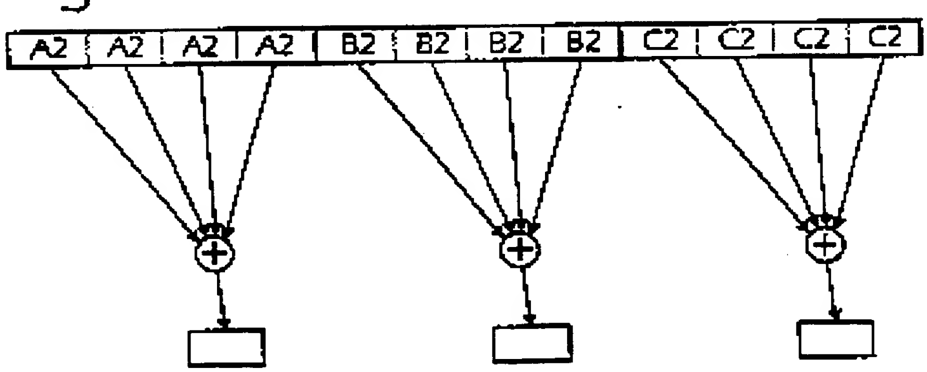


Fig. 3a



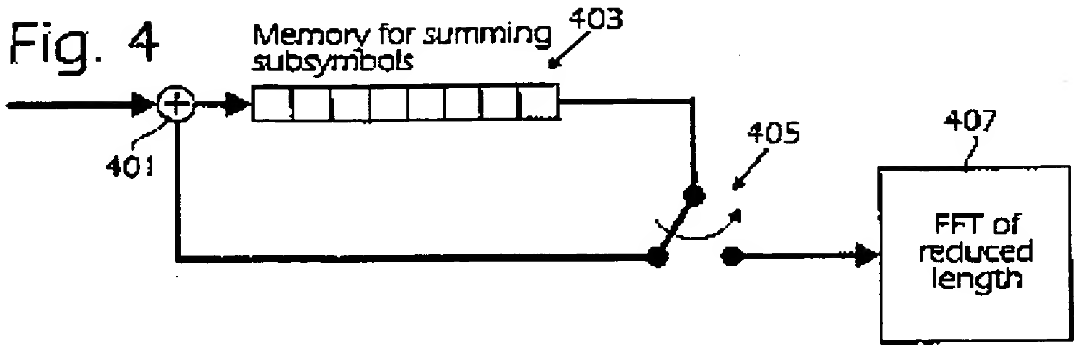
Two subsymbols are added (symmetric case)

Fig. 3b



Four subsymbols are added (symmetry 1:4)

Fig. 4



(SYMMETRY FACTOR R = 4)

Fig.5a

carrier wave which can be used in the upstream channel

carrier wave which can only be used in the downstream channel

Fig.5b

carrier wave which has been assigned from the upstream channel to the downstream channel

PCT

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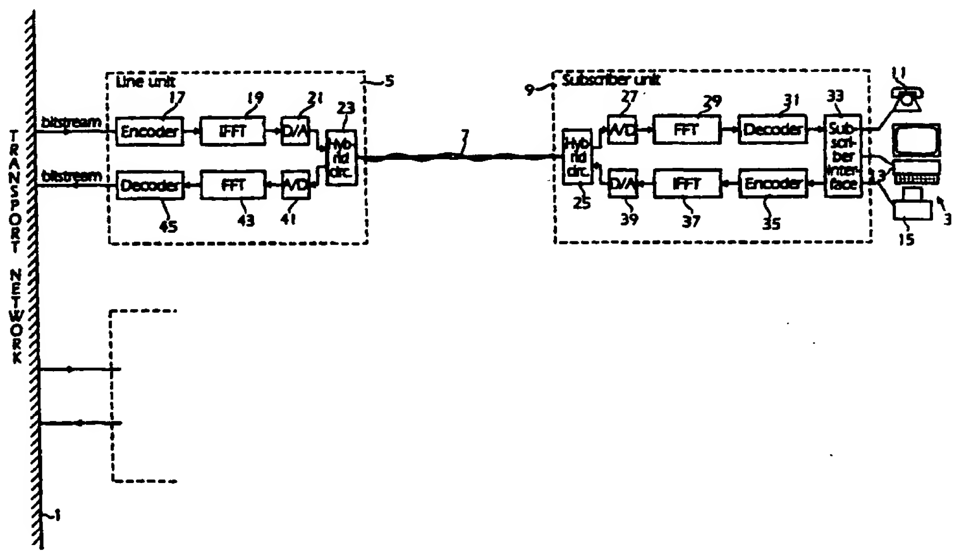
(54) Title: A DIGITAL SYSTEM FOR SUBSCRIBER LINES ALLOWING HIGH BIT RATES

(57) Abstract



A subscriber line connection for very high bit rates in a telecommunication network comprises a line unit (5) connected to a transport network (1) and through a twisted two–wire cable (7) to a subscriber unit (9). Information is communicated bidirectionally on the cable using frequency multiplexing on orthogonal carriers. The line and subscriber units each comprise modulating units (19, 37) determining an inverse discrete fourier transform on incoming symbols and demodulating units (29, 43) for making a direct discrete fourier transform on a sampled stream of the signal forwarded on the cable (7). The transforming units (19, 29) used for transmission in one direction use carriers which are different from those used by the transforming units (37, 43) in the opposite direction. The carriers are selected so that in at least one of the directions special properties of the transforms are used for reducing the number of calculations which are required. In the direction from the subscriber (3) only carriers having even indices can be used in the transforming unit (37) and then the output signal sent on the cable (7) will consist of a repeated sequence having half the length of that obtained when all carriers are used, so that only a sequence having half the length has to be calculated and repeated. In the transforming unit (43) receiving such a twice repeated signal, the received symbols can be subdivided into two equal segments which are added to each other and then a reduced transforming operation is executed. In the opposite direction the transforming operation using all carriers can always be calculated. Then also, the lowest frequencies can be always assigned to this direction towards the subscriber, since the transmission in the opposite direction may be especially sensitive to noise or interference at low frequencies which thus should not be used.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 98/01283

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H04L 5/06, H04L 27/26
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H04B, H04L, H04J

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Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	IEEE Transactions on Communications, Volume 40, No 6, June 1992, Antonio Ruiz et al, "DISCRETE MULTIPLE TONE MODULATION WITH COSET CODING FOR THE SPECTRALLY SHAPED CHANNEL", page 1012 - page 1015, figure 1, paragraph V, VI --	1-7
Y	WO 9706619 A1 (TELIA AB), 20 February 1997 (20.02.97), page 2, line 26 - line 39; page 3, line 26 - page 7, line 36, cited by the applicant --	1-7
Y	EP 0668678 A2 (ITALTEL SOCIETA ITALIANA TELECOMUNICAZIONI S.P.A.), 23 August 1995 (23.08.95), column 2, line 38 - column 5, line 21, abstract, cited by the applicant --	1-7

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Date of the actual completion of the international search	Date of mailing of the international search report
19 January 1999	22-01-1999
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Irenne Turcu Telephone No. +46 8 782 25 00

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 98/01283

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0616445 A1 (FRANCE TELECOM), 21 Sept 1994 (21.09.94), figures 2,3,4,5, abstract, cited by the applicant --	1-7
A	IEEE Transactions on Communications, Volume 33, No 7, July 1985, Leonard J. Cimini, Jr., "ANALYSIS AND SIMULATION OF A DIGITAL MOBILE CHANNEL USING ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING", see the whole document, cited by the applicant -- --------	1-7

INTERNATIONAL SEARCH REPORT

Information on patent family members

01/12/98

International application No.
PCT/SE 98/01283

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9706619 A1	20/02/97	SE 9502775 A	05/02/97
EP 0668678 A2	23/08/95	IT 1273794 B IT MI940312 D,U,V	10/07/97 30/10/95
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